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ABSTRACT

This paper reports on the technological aspects of an international study in which secondary students engage in authentic data inquiries involving the posing, sharing, and critiquing of statistical word problems. This paper focuses on investigating the use of Web-based intranets to enable schools to conduct collaborative statistical investigations with students from other countries using the Internet. A series of exploratory case studies in classrooms in England, Australia, and Canada in which students posed and shared problems involving measures of central tendency are provided. The principal sources of evidence were the following: all materials posted to various areas of the project Intranet, video recordings, observers' notes, e-mail, and teacher interviews. The purpose of this paper is to discuss issues that have emerged in the present application of computer-mediated communication for fostering mathematical problem posing and critiquing. The central conclusion is that semi-private Web-based intranets present an excellent medium for publishing, sharing, and discussing mathematics problems created by students. Contains 59 references. (ASK)

Using Intranets to Foster Statistical Problem Posing and Critiquing in Secondary Mathematics Classrooms

Donald H. Cudmore

Oxford University Dept. Of Educational Studies

Lyn D. English

Queensland University of Technology

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USING INTRANETS TO FOSTER STATISTICAL PROBLEM POSING AND PROBLEM CRITIQUING IN SECONDARY MATHEMATICS CLASSROOMS

This paper reports on technological aspects of an ongoing international study in which secondary students engage in authentic data inquiries involving the posing, sharing and critiquing of statistical word problems.

This is part of a larger study, which aims to:

1. investigate developments in students statistical understanding and reasoning processes as they engage in authentic data investigations involving data modeling, statistical problem posing, and problem critiquing;
2. foster students' awareness and appreciation of the influence of cultural factors in the statistical understandings of their international peers;
3. investigate the use of Web-based Intranets to enable schools connected to the Internet to conduct collaborative statistical investigations with students from other countries;
4. use the findings of the study to develop a conceptual model of students' growth of statistical understanding.

In this paper, we focus on aim #3 and consider our developing experience in using semi-private sites on the World Wide Web to facilitate activities in which students both publish mathematics problems that they have created and provide structured comments on problems posed by their local or international peers. To date, we have conducted a series of exploratory case studies in classrooms in England, Australia and Canada in which students posed and shared problems involving measures of central tendency (mean, median and mode). The problems were based on the results of an authentic, international dataset which they helped to create. The purpose of this paper is to discuss issues that have emerged in our present application of computer-mediated communication for fostering mathematical problem posing and critiquing. More specifically, we consider the following issues:

- the emergence of the Intranet design over the initial phase of the research project;
- the impact of the Intranet design on the effectiveness of computer-mediated communication in the key stages of the project;
- the implications for subsequent Intranet designs for networked collaborative problem-posing activities

1. Internet Technology in School Classrooms

There is increasing interest in the use of the Internet in educational settings (Clinton, 1997; Downing & Rath, 1997; Shotsberger, 1996). As Perks, Gavitt and Olivo suggest, "no longer is the question *if* the Internet will be used in the classroom but *when*" (1997, p. 147). As of March, 1998, an international registry of schools on the World Wide Web (http://web66.coled.umn.edu) reports that more than 11,500 schools from 79 countries have web sites, and the number of schools on the Internet has grown steadily each month since the registry was begun in 1995.

The increasing profile of research into educational technology was reflected in an Interactive Symposium at the 1997 AERA Annual Meeting (Fishman et al., 1997). In the introduction to the symposium, it was noted that various educational researchers had been studying the Internet and related networking environments for more than 10 years, beginning with such tools as e-mail, electronic conferencing, and shared databases (eg. Harris, 1995; Levin, Rogers, Waugh & Smith, 1989; Riel & Levin, 1990; Rogers, Andres, Jacks, Clauset, 1990; Scardamalia & Bereiter, 1992). This research showed that communication technology enabled students to interact with others in ways that transcended the constraints of time, place, and scale of a traditional classroom environment. Communication technology was also valuable in that it provided students with access to distributed materials which could be discussed or worked on with others inside or beyond the classroom (Fishman et al., 1997).

What was sometimes less recognised, though, was the value of communication technology in structuring educational interactions -- making it not only possible but *easy* to do certain things (Hoadley, 1997). This can be seen in the present explosion of interest in the World Wide Web. The development of browsers such as Netscape and Internet Explorer has greatly changed the ease of Internet-based communications. This, combined with dropping hardware and connection costs, means that communications that once were largely restricted to specially equipped, exemplary educational settings, are now accessible to any schools with Internet connections and web browsing software.

In the fields of mathematics and mathematics education, the World Wide Web is revolutionizing the way a subject can be discussed, taught, and explored (Klotz, 1997; Arnold, Shiu and Ellerton, 1996). In a vivid hypertext essay (http://forum.swarthmore.edu/articles/epadel/index.html), Klotz illustrates how the World Wide Web has become:

- a repository and conveyer of instructional resources and course materials for local and distance mathematics education;
- a medium for the delivery of entire courses (especially for distance learning);
- a place where mathematicians, teachers and students can discuss mathematical ideas and publish them, formally or informally, in text and hypermedia;
- a place that fosters the formation of new mathematical communities;
- a place where numerical data can be located, collected and shared;

- a place where mathematical software can be published, purchased and demonstrated;
- a place for virtually hosting professional organizations and programs for curricular reform (such NCTM's Standard's 2000 Project).

In this era where access to the World Wide Web and electronic mail is becoming increasingly ubiquitous, there is insufficient research available to guide policy makers and educators in the best uses of this technology in typical educational settings (President's Committee of Advisors on Science and Technology, 1997). However, it appears clear that the absence of research is not delaying the connection of schools to the Internet. The rapid emergence of the World Wide Web and its broad deployment in schools highlights the great need for new educational models that can guide efforts to make best use of the particular features, possibilities and constraints of the World Wide Web (Harasim, 1997). In particular, there is a need for both exploratory and large scale confirmatory research into ways that this emerging technology can be employed to foster the development of students' higher order thinking (President's Committee of Advisors on Science and Technology, 1997).

Intranets

One concept in networking technology that has emerged as a result of the development of the Internet is called an *Intranet*. Many corporations and organizations for internal communication and collaboration (Bernard, 1998; Pfaffenberger, 1998) have aggressively adopted the Intranet approach to computer networking. Intranets use the open architecture of the Internet in private or semi-private networks. A semi-private network (commonly referred to as a virtual private network or Extranet) is one that is accessible via the Internet to authorized users who know the address (called a URL) and any passwords required. In this approach, different users are given different levels of authorization and this restricts which areas of the internal network are accessible to them at any given time. In the business world, the private part of the Intranet is used for internal communication within a company; the semi-private part of the technology is used to interact (with appropriate levels of security) with suppliers, customers, or both (Pfaffenberger, 1998).

Harasim (1997) decried the fact that most educational uses of Web-based technology were directed at publishing static information rather than building knowledge and fostering educational interactions; however, she predicted that this would soon change as educators sought to find more productive uses of the technology. Downing and Rath (1997) suggest that Intranets provide the next key link along the route to future "electronic classrooms". The interest in Intranets for education would appear to be growing, as evidenced by the very recent (March 1998) introduction of a new generation of Intranet servers designed especially for schools (The First Class Collaborative Classroom™ Intranet Server).

One attraction of an Intranet is the variety of "GroupWare" services it can provide to its users. It is beyond the scope of this paper to discuss these in detail (see Bernard, 1998; Pfaffenberger, 1998 for more information), but Intranets can be designed to provide: electronic mail, mailing lists, file archives, live conferencing, shared databases and numerous other features. For the purposes of this paper, we will simplify our consideration to two practical capabilities of a semi-private Web-based Intranet. First, is the ability to serve web pages to *authorized* individuals anywhere in the world (provided they have an Internet connection and any required passwords); and, second, the ability to automatically accept, process and distribute data using Web-based interactive forms (Anthony, 1996; Bernard, 1998).

The communication services that Intranets may provide (such as e-mail, electronic conferencing, video conferencing, etc.) have been investigated in educational settings (Fishman et al., 1997; President's Committee of Advisors on Science and Technology, 1997)and there has been a proliferation of networks that can provide many such services (such as The Global Schoolnet (www.gsn.org) and the Math Forum (www.forum.swarthmore.edu)). However, the Intranet concept and the notion that schools and educational projects should develop their *own* virtual private networks have received little explicit attention in the existing literature on educational technology.

An exception to this is a recent case study by Downing & Rath (1997). An Intranet was used in administering regular quizzes in two university courses. After students wrote their quizzes in class, all subsequent information and discussion about these quizzes were handled through an Internet-based Intranet. Thus, students had to access the Intranet to find correct answers, to locate their grades, and to determine their achievement level relative to the rest of the class. The Intranet's bulletin board was also the only place where the professor and the teaching assistant would entertain any questions pertaining to the specific content or grading of the quiz. At the same time, students were encouraged to use e-mail and the electronic bulletin board for other purposes of their choosing. Downing and Rath reported that students responded positively to the Intranet, and that it significantly reduced administrative time spent on the quiz aspect of the course. Their research was conducted in 1994 before the World Wide Web became broadly available, and therefore their communications were conducted through more primitive electronic bulletin boards and e-mail. Downing and Rath report, however, that since that time they have moved services for at least one of the courses over to a Web-based Intranet. Similar, positive results have been obtained.

A vital aspect of Downing & Rath's conclusions was that a successful implementation of an Intranet, as a collaborative communication network, required that users be *forced* to use it in at least one activity that is of interest to them (1997, p.286). In their case, students had to use it to get their quiz grades. In the present research, the students had to use the Intranet to fill out surveys, access statistical data, and participate in "mathematical problem posing and critiquing" activities with students beyond their own classroom. The terms "mathematical problem posing" and "problem critiquing" are explained in more detail in section 2.

Computer-Mediated Statistical Inquiry

The architecture of the Internet is well suited to the automated collection, analysis and display of statistical data. This technology is used in many private and semi-private Intranets to efficiently deliver and process attitude surveys within organizations (Bernard, 1998; Pfaffenberger, 1998). A web site called React.com (http://www.react.com) which provides a place, targeted at young people, where opinions are solicited uses a similar approach and the results published. This kind of site encourages younger visitors to think about data, how it can be handled, displayed and used to draw conclusions.

There is evidence to suggest that students can become especially interested in handling data that they help to generate (Sanders, 1996; Somers, Dilendik, & Smolansky, 1996). Typically, such data is generated within the classroom. However, with schools becoming connected to the Internet, teachers can have their students conduct collaborative statistical investigations with students from other countries. Sanders (1996) provides a helpful example of this in his chronicle of such a collaboration. In his project, his United States high school students wrote an opinion survey which contained Likert-scale statements about a variety of issues relevant to teenagers. His class and a class in Iceland, contacted via an Internet mailing list, filled out the survey and each class analysed the results using means, standard deviations, and t-tests of independent means. Survey data were shared between the classes via e-mail. Sanders' project is particularly interesting in that it concluded with an on-line Internet "chat" session between representatives of each class. This provided these students with an opportunity to probe the cultural factors that might *explain* similarities and differences in the opinions of each class (on gun control and interracial marriages, for example).

Problem-posing activities lend themselves ideally to students' statistical inquiries. Problem posing is a natural component of authentic data-based investigations, especially when students and teachers work within a collaborative learning community (Brown, Ash, Rutherford, Nakagawa, and Gordon, 1993; Lehrer & Romberg, 1996; Scardamalia & Bereiter, 1992).

2. The Problem Posing and Critiquing Activity

Mathematical Problem Posing

In his seminal review of the literature on mathematical problem posing, Silver (1994) indicated that problem posing could refer to both the generation of new problems and the reformulation of existing problems. Furthermore, posing can occur before, during or after the solving of a given problem. In our studies, however, we use the term "problem posing" to refer more specifically to cognitive activities in which the *ultimate* goal is not the solution of an existing problem, but rather the creation of a new or extended problem.

The important role of problem posing in the mathematics curriculum was recognized several decades ago by Polya and later by Halmos. As these eminent mathematicians stated:

> The mathematical experience of the student is incomplete if he never had an opportunity to solve a problem invented by himself. (Polya, cited by Brown, 1987, p. i)

> The mathematicians' main reason for existence is to solve problems... I do believe that problems are the heart of mathematics and I hope that as teachers, in the classroom, in

seminars, and in the books and articles that we write, that we will emphasize them more and that we will train our students to be better problem posers and problem solvers than we are. (Halmos, 1980, p.524)

More recently, there has been a growing interest in promoting problem-posing activities in the classroom (Brown & Walter, 1993; Ellerton & Clarkson, 1996; English, 1997a, 1997b, 1997c, 1998a; English & Cudmore, 1998; English, Cudmore & Tilley, in press; English & Halford, 1995; Silver & Cai, 1996; Silver, Mamona-Downs, Leung, & Kenney, 1996; Silverman, Winograd & Stronhauer, 1992). The Curriculum and Evaluation Standards (NCTM, 1989) recommends that problem posing be included in the secondary mathematics curriculum: for lower secondary levels they recommend that students should be given the chance to pose problems that reflect their personal interests; for upper secondary, it is suggested simply that students "should have some experience recognizing and formulating their own problems" (1989, p. 138).

Despite the fact that problem posing lies at the heart of mathematical activity and is fundamental to mathematical competence in both academic and vocational contexts (Brown & Walter, 1993; NCTM, 1995), it has received minimal research attention (English, 1997c, 1998b; Silver, 1994; Silver & Cai, 1996). Prior to our studies on the use of the World Wide Web to foster students' problem posing, we had spent three years researching the posing and sharing of student-generated mathematics problems in a variety of classroom contexts (Cudmore, 1996; English, 1997b, 1998b; English et al., in press). In more than a dozen classrooms, we collected several hundred "mathematical story problems" (Silverman et al., 1992) written by 12 to 15 year old children, and concluded that students were generally able to formulate reasonably complex, solvable problems -- usually with contemporary contexts -- which their peers enjoyed trying to solve; it was also observed that the problem authors took considerable pride in their problem creations (English et al., in press).

In one phase of our previous research, students posed statistical word problems based on the results of a survey that was planned by one class and administered to two other classes. After the survey results were collected, students in all three classes were engaged in activities where they posed and shared statistical problems. These problems required measures of central tendency to be calculated and the solver to make a decision or discovery about some aspect of the data. Cudmore (1996) found that observations of students engaged in formulating, solving, and sharing original statistics problems yielded a rich context for a dynamic analysis of the growth of understanding of basic statistical concepts such as the mean, median and mode.

In our explorations of various ways to foster problem posing, we have found that it is valuable to give students an opportunity to exchange problems' with their peers and to receive feedback from them (English et al., in press). However, we believe that it is important to structure both the exchanges and critical student feedback. We call this structured feedback process "problem critiquing", which is described in more detail in the next section.

Problem Critiquing

In our studies of mathematical problem posing, we have been interested in the notion of "publishing" student story problems and in exploring approaches for offering appropriate feedback to problem authors. The importance of publishing for an audience -- beyond just the teacher -- has been widely noted in the literature on language education (eg. Graves, 1983, 1994). However, as Silver has lamented, "students are rarely, if ever, given opportunities to pose in some *public* way their own mathematics problems" (1994, p.19, emphasis added).

In the practitioner-oriented literature, there are several examples where mathematics teachers have given student-posed problems an audience by including them in worksheets, class "textbooks", or even tests (cf. Bush & Fiala, 1986; Fisher, 1993; MacLeod, 1992; Odafe, 1998; Silverman et al., 1992; van den Brink, 1987). Other teachers have adapted the "author's chair" (Graves, 1983) approach in language arts to mathematics instruction, in which a set amount of time is regularly set aside for a single student or group of students to share their posed problem with the entire class (Hicks & Wadlington, 1994; Silverman et al., 1992). In a few cases, students receive direct feedback from fellow students concerning their problems and are encouraged to improve or extend them (Brown & Walter, 1993; English, 1997b; English et al., in press; Silverman et al., 1992; Winograd, 1991).

In our own research, we have conducted a series of studies to explore what happens in activities where secondary students pose mathematical problems and provide structured feedback on problems written by fellow students. We call these "problem posing and critiquing activities" (English et al., in press). To begin critiquing someone else's problem, the student must first try to solve it. After they have solved it, they fill out a short questionnaire (see Appendix A) which asks them to comment on several features of the problem. The questionnaire, called a "critique sheet", has evolved as a result of our classroom studies in which we've gathered several hundred such critiques. In the critique, the student is asked to judge what they like most and least about the problem, and comment on whether the problem is solvable. Next, they are asked to judge the difficulty of the problem, the clarity of its wording, and its interest level; students are also required to justify their judgments. Most importantly, students are asked to offer at least two suggestions to the author for improving or extending the problem. The critique sheet is intended to encourage students to reflect on the problem and critically analyze it. At the same time, reflecting on other people's problems has a synergistic effect in encouraging students to think more carefully and critically in their own problem posing (English, 1998b).

In our previous studies of "student critiques", we found that the short questionnaire was a useful pedagogic device to focus students' attention on the task of solving another student's problem. We observed students, who, as one teacher described "normally couldn't care less", become especially engaged in their mathematics lessons. Even during the last lesson of the school year we have observed entire classes of students totally immersed in sharing and critiquing problem creations.

In general, we have observed that students were usually keen to solve *other* student's problems and they liked being given the opportunity to offer their opinion on critique sheets. Problem authors were typically eager to read the written critiques that peers had completed. Students appeared to have relatively little difficulty deciding on tick-box style ratings for various features of the problem. However, many found it more difficult to provide reasons *why* the problem deserved the rating that they gave it. Frequently, students were able to provide suggestions to help the author improve or extend their problem. However, there was considerable variability in the quality and quantity of suggestions provided.

In the present study, it was thought that computer-mediated communication might make the publishing experience more meaningful, enhance the ease with which problems could be exchanged, and provide interesting opportunities for cross-cultural interactions for the students. However, in investigating the electronic version of the activity we chose to investigate this in a context that was reasonably similar to ones that we had tried previously. We have used the critique sheets in a variety of mathematical contexts, and we selected one of these -- data handling -- as the context for the present study. It was a particularly attractive context, because of the added dimension of being able to use the Intranet to have cross-cultural sharing of *data* as well as exchanges of problems and critiques. The following section describes our approach to applying the Problem Posing and Critiquing activity to a statistical inquiry, which involves authentic survey data.

Adapting the Problem Posing and Critiquing Activity to a Statistical Inquiry

The major steps in the activity are presented in Figure 1. The figure reflects the two roles that students assume during problem posing and critiquing activities. The descriptors "student as author" and "student as critic" are adapted from Brown and Walter (1993, p. 7).

In Steps 1, 2a, and 2b, of Figure 1, the teacher's objective is to ensure that students are immersed in a stimulating context for problem posing, and that they gain experience with the statistical skills they will need to investigate the authentic data. In Step 1, students participate in generating a set of authentic data. In a similar vein to Sanders (1996), students are asked to brainstorm possible questions that would be "interesting and appropriate" to ask students their age in a survey.

In a previous study in Oxford (Cudmore, 1996), Year 10 students (aged 14-15 years) brainstormed questions in a whole class discussion. Selected questions were put into a survey and this was filled out by two Year 9 classes taught by the same teacher. All three classes then posed and critiqued problems, which made use of the results of the survey. In the present study, two classes from Oxford and one class in Australia contributed questions to a common survey. This survey was posted at the Intranet, and later filled out on-line by the students. The raw results of the survey were regularly updated in a special area of the Intranet, and these were used by the teachers in content area instruction and in the later problem posing and critiquing steps.

In Steps 3, 4 and 5 the teacher's objective is for the students to select an aspect of the results that interests them, and then create and attempt problems involving this subset of the data. A key feature of these problems is that they should require the problem solver to make a decision or discovery on the basis of the data referred to in the problem. Examples of a student-generated statistical problems are presented in Figure 2.

When students consider their problem is ready for another student to work, they "publish" it in draft form (Step 6). If students are unhappy with their problem before others try it, then they may alter their existing problem (Step 4) or return to examine another area of the survey results (Step 3). After other students attempt and critique their problem (Steps A, B, C, D), the student receives feedback (Step 7) and may once more decide to make major or minor changes to the problem. Finally the students submit a final version of their problem (Step 8).

In the electronic version of the activity, students typically did a "local" exchange of their handwritten problem with a classmate, who provided them with initial feedback. After this, the author published the problem, and any subsequent revisions of it, to a special directory at the Intranet. At the conclusion of the activity, their final problem was the version posted most recently. Problem critics selected the latest versions of problems and obtained the necessary raw data for each problem via the Intranet. After solving a problem, the problem critic filled out an electronic critique and submitted it to a special directory at the Intranet. After problems had been shared and critiqued within the class, they were made available to students from other locations to try. Authors could view the feedback for their problem in a special directory at the Intranet.

Importantly, in the present study the problems and critiques could be accessed remotely via the Internet -- provided the student knew the location of the appropriate Intranet directory and any required passwords. Thus, it was possible for students to submit problems, revisions, and critiques outside of regular class hours, and from any computer -- at home or school -- connected to the Internet.

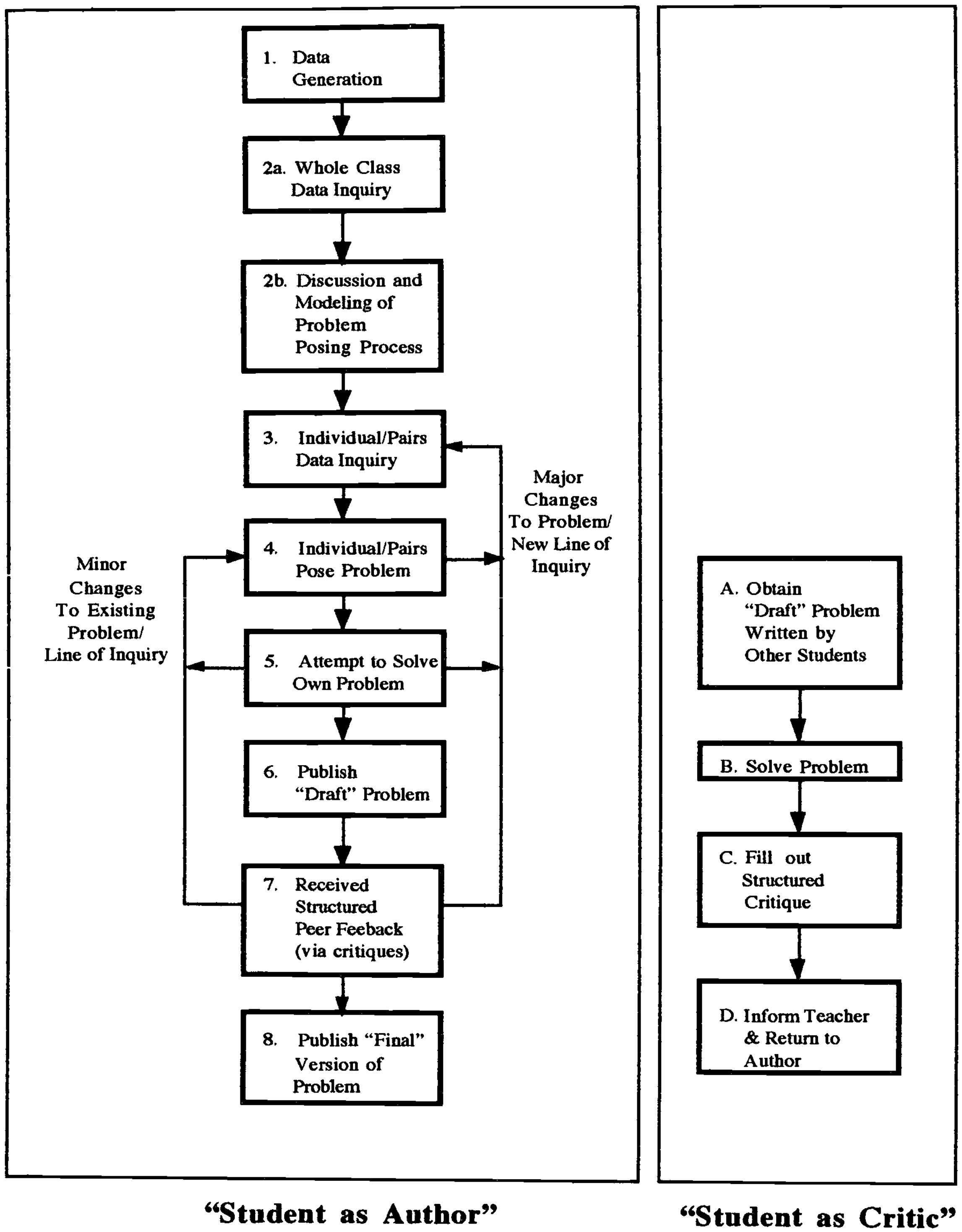

Figure 1 Steps in the Statistical Problem Posing and Critiquing Activity.

Authors: Catherine, Megan, and Nicole, Grade 9 -- Brisbane, Australia
Title: Variety is the SPICE of life
Date: 08/28/97, 20:20:05 (California time)

It was a quiet day in England, when Mel C (sporty spice) awoke from her slumber and approached the Spice Girl's magic mirror. She questioned the mirror, "Mirror, mirror on the wall, who is the most popular Spice of all?" The mirror replied, "Look at the data and you will see, it's not Mel C, maybe Mel B!" Solve the following questions:

1) Who is the most popular Spice Girl to Australian girls?
2) Who is the most popular Spice Girl to Australian boys?
3) Who is the most popular Spice Girl to UK girls?
4) Who is the most popular Spice Girl to UK boys?
5) Who is the most popular Spice Girl overall?

Is Mel C right? Is the mirror right? Or are they both wrong?
NB It may help to put the first four questions in percentage form, in order to solve question 5.
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additional parts posted: 11/12/97, 15:29:03 (California time)

What formula's did you use in order to solve this problem?
Were you expecting this outcome? Why?

Author: Elizabeth -- Toronto, Canada
Title: Dozing in Math
Date: 11/28/97, 10:31:26 (California time)

One Morning Mrs. {Teacher's Name} came into her classroom to see that some of her students were sleeping in her class! 'Does the amount of sleep my students get on weeknights affect their alertness in myclass?' Mrs {Teacher's Name} asked.
Answer the following questions:

a. Find the range of bedtimes on weeknights for Canadian and Australlian results.
b. Find the median of bedtimes on weeknights for both countries.
c. Find the mean bedtime for each bedtime on the weeknights for both countries.
d. Find the average bedtime for each coutry and find out which counrty would be more alert for {Teacher's Name}} math class.

Figure 2 Examples of Student-Generated Statistics Problems

3. Investigating the Intranet Design

The Intranet Design

The Intranet was designed to meet several needs. It supported communications amongst the project team, and provided places where entire classes of students could share data and mathematics problems. Numerous design choices needed to be made, and a narrative describing the early development of our Intranet is presented in Appendix B.

Two aspects of the design were especially important: the ability to display Web pages to authorized users; and, most importantly, the ability to accept, process and distribute data using Web-based interactive forms. From the perspective of user access, the site was divided into four zones. The public area of the site was unrestricted and accessible via the "main public home page" (www.ourquestions.com). Other zones were effectively "workplaces" for individual classes, the project team (teachers and researchers), and the Intranet designers and administrators (called Webmasters), respectively. Specific web pages on a site could be given various levels of privacy (Bernard, 1998; Pfaffenberger, 1998).

The "main public home page" (Figure 3) was used to provide background information about the project and act as a gateway to other zones. Each teacher typically had a "classroom home page" (Figure 4) which contained a set of updated links to Web pages (locally or on the Internet) needed for particular lessons. The "Internal Intranet Home Page" was password protected and intended to serve as a directory of active Discussion Forums and documents relevant to the project team. The Intranet also contained pages related to the Data Generation stage of the activity (Step 1 of Figure 1). These included the on-line survey of questionnaire items suggested by students (called the "International Survey"), as well as pages displaying raw survey results for students to analyse.

A key capability of the Intranet was its ability to automatically process data submitted by users to on-line forms. Figure 5 is a list of automated actions that are invoked when a particular on-line form is submitted. The number and nature of automated tasks is an important consideration when investigating means to improve the effectiveness of the Intranet; this will be explored further in Section 4.

Two types of Electronic Forums were used to facilitate group communication: "Special Discussion Forums" and "Problem Posing and Critiquing Forums". Special Discussion Forums were single-threaded hypertext-based discussion lists, designed especially for this project (Aczel & Cudmore, 1998). These combined key features of Internet *newsgroups* and *mailing lists* in a browser-based environment that could incorporate various levels of password protection. The feature borrowed from newsgroups was its ability to act as a bulletin board for random messages on a particular topic; from mailing lists came the idea that it should automatically send e-mail messages to designated subscribers whenever a new message was added to the Forum. Unlike a mailing list, however, it did not require users to have an e-mail account to view and contribute to the discussion (though an e-mail account would be needed for automatic notification). Furthermore, it had the advantage of accepting regular text or HTML. Thus, users could embed links *to* other pages and graphics *from* other pages, if they chose to.

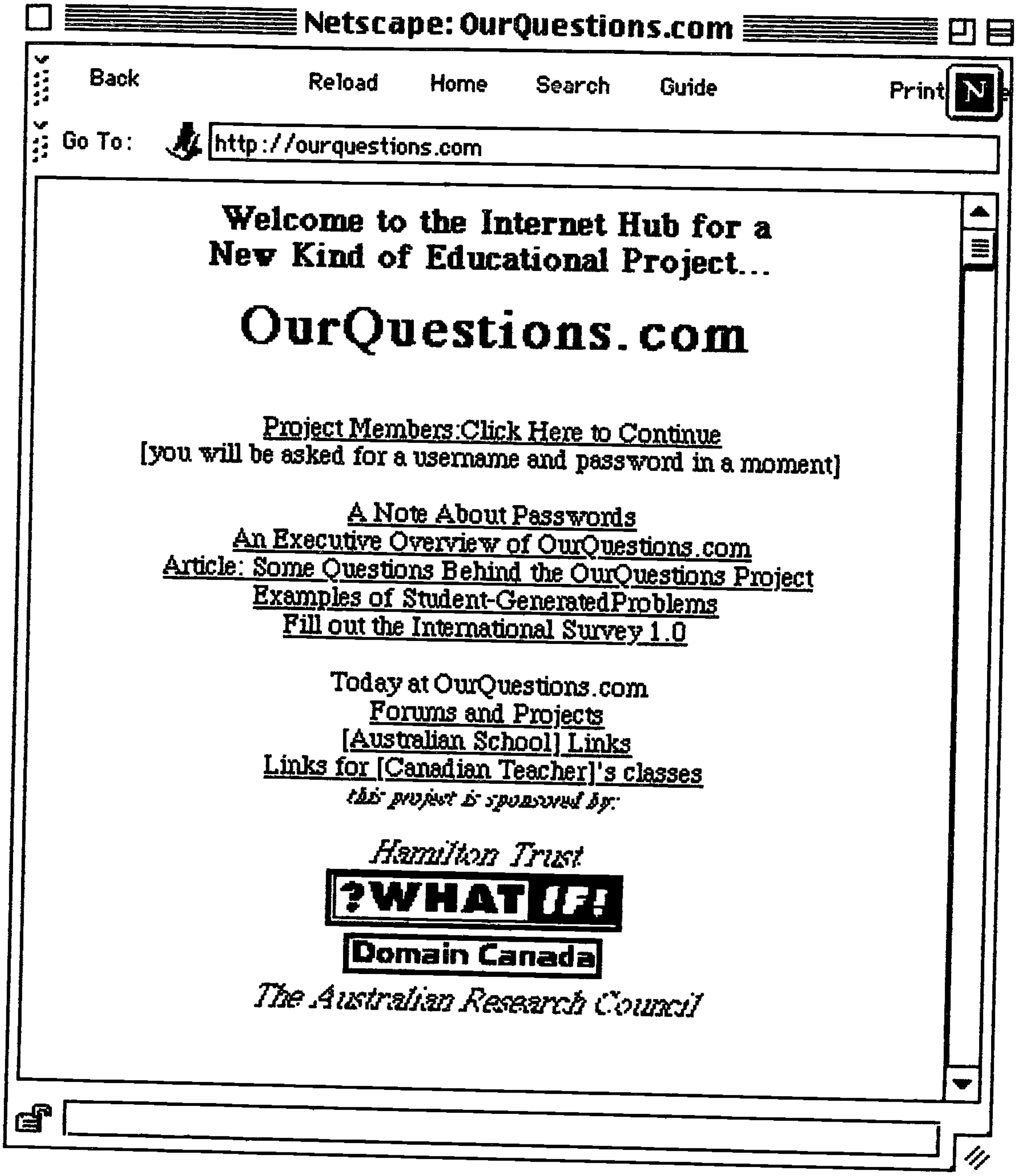

Figure 3 - Main Public Home Page

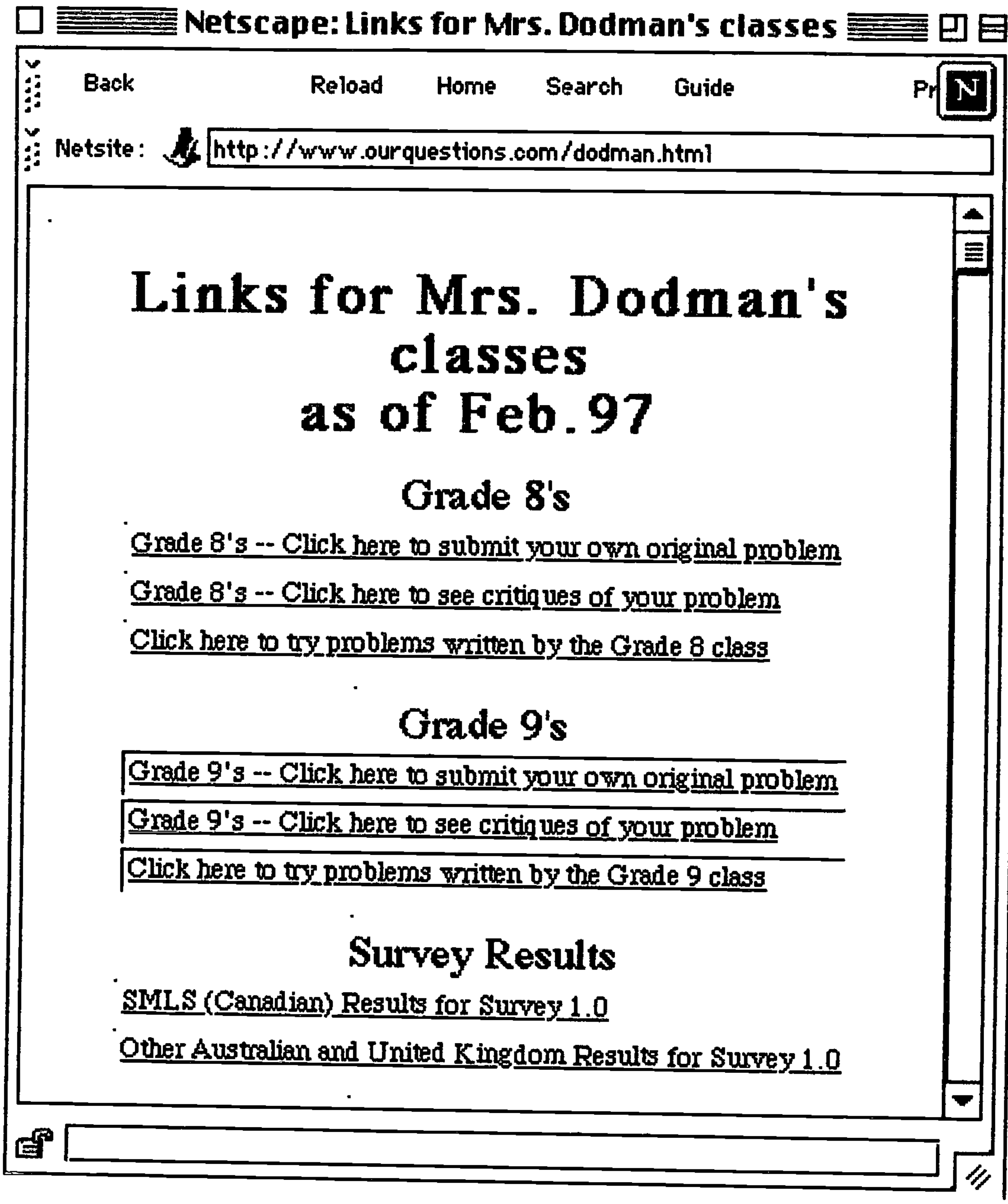

Figure 4 - Classroom Links Page

When user does the following...

The Resulting Actions are Taken Automatically

1. Submits completed "International Survey" form

1.1 "Thank you" screen displayed
1.2 E-mail notification sent to distribution list (project team)
1.3 Data added to text file (for incorporation into database for future publishing at Intranet).

2. Submits Message to Discussion Forum

2.1 "Thank you" screen displayed
2.2 E-mail sent to distribution list
2.3 Index page revised
2.3 Message page created
2.4 optional: add users e-mail to distribution list

3. Submits Mathematical Problem

3.1 "Thank you" screen displayed
3.2 E-mail notification to distribution list (teacher/project team)
3.3 Index page revised for list of Problems (new problem at top of list)
3.4 Problem published

4. Submits a Problem Critique (accessed from Link on Problem Page)

4.1 "Thank you" screen displayed
4.2 E-mail notification to distribution list (teacher/project team)
4.3 Problem Critique Index updated
4.4 Critique page created

5. Discussion Forum Generator (restricted to Intranet Webmaster)

5.1 Index page created
5.2 Message submission page created
5.3 Welcome message created
5.4 E-mail list (optional) created

6. Problem Posing and Critiquing Forum Generator (restricted to Intranet Webmaster)

6.1 Problem Forum created
(including index, welcome, message submission pages)
6.2 Critique Forum created
(including index, welcome, message submission pages)

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7. Future Generators: Brainstorm Generator, Survey Maker, Classroom Links Generator (to be implemented in next phase)

Figure 5 Automatic Actions Taken When Web Page Processes Form

A Discussion Forum at our Intranet had three principal parts: an "index page" to display a tabular index of the messages sent to the Forum; "message pages" to display the full text of individual messages; and, an on-line form called the "new message entry page". Each part contained hypertext links to the other two parts.

Special Discussion Forums were used by one class to brainstorm possible questions for the International Survey. Special Discussion Forums were regularly used by the project team to plan, conjecture, offer progress reports, and present observational data. They were used by students in one class to brainstorm possible questions for the International Survey. As new discussion threads were needed, links would be made from the existing Forum to this new discussion. For example, many of the initial project discussions were recorded in the "Forum for the Pilot of the Electronic Critique Sheet" (http://www.ourquestions.com/Forum/Thread3). When this pilot study was concluded, a new "Forum for the Initial Study of Students Investigating Authentic Data" was created, and hypertext links were made between it and related Forums. Discussion Forums were typically created for very defined purposes and specific time frames. Once a Forum was no longer needed for planning and executional purposes, it served as an automatic archival record of what had transpired during the "active life" of the Forum.

In translating the Problem Posing and Critiquing Activity to an electronic environment, a modified arrangement of two interlinked Special Discussion Forums was devised. One Forum was used to collect and display problems written by students. Each participating class had its own Forum. Critics could browse these problems, and after they selected a problem and tried to solve it, they could press a link to fill out an Electronic Critique. When critiques were submitted they were published in a companion Forum.

Methodology

The Intranet plays a complex role in the larger research study. To address the project's aims, as described at the outset of this paper, it was first necessary to establish the feasibility of the project Intranet and to refine both its design and our procedures for using it.

To address this aim, the first year of the ongoing three-year study was devoted to exploratory studies conducted within a qualitative, naturalistic framework (Lincoln & Guba, 1985; Janesick, 1994). The majority of our fieldwork was conducted in "natural" (ibid.) classroom settings, in which students interacted with the Intranet web site. The researchers were participant observers, who collaborated with the classroom teachers in planning and conducting the activities. Table 1 lists the chronological sequence in which fieldwork was conducted. An analytic induction method was used to examine the evidence collected, with the purpose of identifying emerging issues and opportunities related to our research aim.

The principal sources of evidence were: all materials posted to various areas of the project Intranet (by students, teachers and researchers), video recordings of students during selected activities, observers' notes, e-mail communications amongst participating teachers and researchers, and teacher interviews. Most of the data were collected in individual classrooms in Oxford (UK), Brisbane (Australia), and Toronto (Canada).

TABLE 1. Chronology and Location of Exploratory Field Studies

Title of Activity	Date and Classroom Location
Critique Form Pilot	3/97 : Oxford, UK
Brainstorming of Questions for the "International Survey"	5/97 : Oxford, UK 5/97 : Brisbane, Australia
Filling Out the "International Survey"	6/97 : Oxford, UK 7/97 : Brisbane, Aus. 7/97 : Adelaide, Aus. 11/97: Toronto, Canada
Electronic Posing and Critiquing	7/97 : Oxford UK 8/97-11/97 : Brisbane, Aus. 11/97-12/97 :Toronto, Can.

4. Observations: Using the Intranet for Statistical Inquiry, Problem Posing and Critiquing

Over the course of this study, more than 80 statistical problems and 100 critiques were published at the Intranet by students (aged 13-15) from 4 classrooms in England, Australia and Canada. In interviews, the teachers from all locations noted the activity had been educationally valuable and interesting for their students. For example, when asked what advice she would give to other teachers considering the activity, one teacher said:

> Don't hesitate to do it. It is a great learning experience for both the students and teacher.

In a short article to the school's newsletter, the teacher added:

> With the connection of [our school] to the World Wide Web, opportunities now exist to use the Internet connection in effective and innovative ways in the classroom... The project not only allowed the students to experience a new way of learning Mathematics, but also provided them with a valuable cultural experience. From their study of the data, they became aware of the cultural similarities and differences of students with whom they would otherwise have had no contact.

It is not unusual in case study research for an investigator to base their report upon key issues, related to the research aims, identified over the course of the study (Stake, 1994). In this exploratory study, verbal and written comments made by teachers, students and researchers -- relating to the technology and its use -- could be grouped according to a number of issues. The items which relate specifically to the use of the Intranet in the classroom are discussed in the sections which follow. Comments that related to the research process itself are outside the scope of this section; however, numerous comments were made concerning the Intranet and its impact on the research process and these are discussed briefly in Appendix C.

Issue 1: Effects of the Intranet design on students' experiences in statistical inquiry

The introduction of an Intranet-based "International Survey" had a dramatic effect on the manner in which the set of authentic data was generated for statistical inquiry, relative to the more traditional "classroom survey" approach that we had used in an earlier study. It was particularly interesting to see, at the teacher's suggestion, how effective Special Discussion Forums were in facilitating within-class brainstorming. In the Oxford brainstorm sessions, more than 400 possible questions were posted by students from two classes in their respective lessons at the computer. This Forum was password protected and restricted to the teacher's two Year 9 classes (aged 13-14 years). The students could put any number of questions into the message. Some students put twenty or more questions on a page. Others put only a few on a page. Several students kept returning to the Forum and adding additional questions as they occurred to them. Afterwards, the Oxford teacher noted:

> The [Forum-based]brainstorming, I thought, was very successful... I am sure that one of the things that contributed to the brainstorming being good was the fact that [the students] knew it was for an *international* survey.

From the student-suggested questions, we selected ones that appeared interesting and involved different kinds of numerical data. These included nominal (eg. "favourite number", "favourite Spice Girl"), ordinal (eg. "how concerned are you about the environment") and cardinal data (including discrete values such as "how many children would you like to have of your own some day"; and, continuous values such as "how long is your hair").

An on-line survey was prepared manually by one of the researchers. Because of the broad overlap in questions, most students saw at least one of their questions appear in the final survey. The teachers were able to get their students to fill out the survey during the next convenient computer-based lesson. The entire survey could be filled out in five to ten minutes, and survey completion went smoothly at each location.

A researcher took the results, processed them in a database and manually converted them into Web pages. This was time-consuming, but necessary, as students needed raw results when they worked on problems posed by other students. Several students were observed "looking for themselves in the data" and there was genuine interest in trying to use the data to make decisions or discoveries.

A simple question such as "Have you ever heard of Pauline Hansen?" encouraged students in Canada and England to ask their teachers "Who *Is* Pauline Hansen, and why have all the Australians heard of her?". In another situation, a group of Australian students appeared surprised that the students in England said they were more concerned about the environment than the Australians did, and they wondered:

> Why would the UK students be more concerned and very concerned about the environment than the Australians? In their responses, are they referring just to their country or to the whole world? Would the statistics and data change in the future? If so, how?

One difficulty in doing statistical investigations with authentic data was that such data were sometimes messy and it rarely provided nice round answers that students were used to obtaining. Another issue was the fact that basic statistical representations such as bar charts and histograms could not be readily included in students solutions -- since students only entered text data into the Forums in this study. Furthermore, some students had problems managing the potentially unwieldy amount of data they could access; others had some difficulty reading the data from the computer screens -- though issues here were mitigated somewhat with subsequent improvements to the user interface for the "Results" Web pages.

Issue 2: Effects of the Intranet design on students' experience in problem posing and critiquing

Students appeared to be particularly pleased with the notion of publishing documents to an external audience. In the Australian study, for example, students were observed to republish problems with enhancements after receiving feedback from the Canadian students, and there was strong evidence at all locations that students were especially interested in what other students said about their problems. In the Canadian component, we observed that the Intranet could be used very effectively to promote exchanges between classes at the same school.

In this study we did not have the opportunity -- due to scheduling constraints -- to have the degree of interaction that we would have desired between classes, but we received clear feedback from students that they wanted more interaction with the students from other countries; especially after spending so much time looking at their mutual responses to the "International Survey".

The following incident was particularly interesting and it only came about because the student problems were placed at the Intranet. The Oxford teacher agreed at the Toronto researcher's request to look at the Canadian problems and select one for special mention. Because the problems were on the Forum, it was easy for the Oxford teacher to go on to the Internet, go through the problems and evaluate them. He was able to use a critique sheet to explain why he had made the choice that he did. All of this took about thirty minutes of his time and he was able to do this at a time that was convenient for him. In a subsequent lesson, the class was told which student's problem had been selected and the class went on-line to view the critique sheet submitted by the Oxford teacher.

The student whose problem was selected was someone whom the Canadian teacher described as not especially confident in mathematics. However, the teacher in England did not know the students personally and made his comments purely on the problem posted. The successful student's parents commented later to her teacher that the whole experience had been a very positive one for their daughter. The student had taken advantage of Intranet's capability to let her publish problems outside of classroom periods -- choosing to publish her problem in the evening, from home. She spent an extended amount of time working on her problem, long after the rest of her class had already submitted their problems, and she clearly exceeded the expectations of her teacher in the final problem she produced.

From a critiquing standpoint, a number of small refinements were made to the electronic critique form itself. For example, originally it was designed so that most key items in the critique had to be filled out in order for the critique to be accepted. In field trials it became obvious that we needed to take away this restriction if only so that students who were part way through a critique at the end of class could at least submit what they had done. We also investigated the question of whether the critic's solutions should be text-based, scanned or entered using a graphics tablet. With the technology available to us, it was found that neither scanning nor drawing on a graphics tablet was satisfactorily fast and easy enough for our purposes. At the same time, it was found that many students were able to provide a clear picture of how they solved the problem using text only. The other principal development question raised at this stage concerned whether author's solutions should appear when a critique form was completed, and this has not yet been resolved.

Issue 3: The Ease of Publishing using the Intranet

The publishing of student problems and critiques in the present study went quite smoothly, overall. Students became readily proficient at publishing their work. In their initial experiences in using the forums, the students asked numerous questions concerning navigation (see next section), but with practice, they quickly became proficient in using them. For example, during the initial study of the Electronic Critique Form, a joint message from the Oxford teacher and researcher observed that "once the students had filled in one critique sheet, the second-time 'round presented few difficulties".

Students were able to submit information to Forums, and this was automatically formatted and placed on the Intranet server. Occasionally, students were observed using the cut and paste features of their computer to quickly make changes when revising and re-submitting enhanced versions of their original problem.

Issue 4: The Speed With Which the Site Could be Accessed and Navigated During Lessons

A major concern at the outset of the field trials was whether each school's connection to the Intranet would be sufficiently robust to handle the traffic generated when entire classes of students tried to access the site at the same time. In the initial trials at the Oxford school it was found that even at the time of day when general Internet traffic was at its peak (afternoons in England), entire classes had no problem accessing the site, submitting forms, and getting timely replies from the Intranet. However, it became apparent we had to think more carefully about Web site navigation, as individual student requests for navigational assistance (ie. "I'm lost", "I went to the wrong page by accident", "Where do I go next?") regularly consumed a substantial amount of the teacher's attention. Excessive navigational questions had the unfortunate effect of preventing the teacher from being able to consistently focus on questions related to the mathematics and the student-posed problems. We made several improvements to the Web page layout to try to address these problems, but near the end of all the Oxford trials the teacher still felt that he had to spend "too much time helping people with the technology".

Based on the teacher's recommendations, we set up a special index page for the Brisbane class, specifically for navigating the Problem Posing and Critiquing Forums and the results of the International Survey. The Brisbane school had no trouble accessing the Intranet, and the special navigation page seemed to work much better, in that the teacher could refer students back to that page whenever they became lost or uncertain as to where to go next.

In the trials in Toronto, the Intranet connection was much slower. This appeared to be a combination of temporary problems at the California server (unrelated to our specific site), and the school having a much heavier load on its local area network relative to the speed of its connection to the Internet (ie. it had insufficient bandwidth for its traffic). In one of the early lessons we had a lot of problems with "slow" pages, especially at the very start of class. So, in the following lesson we used a page of links designed for just that lesson (Figure 6), and before class we pre-loaded the pages into the browser of each computer in the room (so it would be immediately available from the browser's cache). During the lesson, the web pages loaded quickly and navigation questions remained at a minimum. Both the teacher and researcher were greatly impressed by how much more material the students were able to cover when the pages loaded quickly and there were few navigation-related questions.

Links for Mrs. Dodman's classes as of Nov. 14/97

- Problems posed by Australian Students at St. Rita's
- English and Australian Results of International Survey 1.0 (as of July 10, 1997)
- Try St. Rita's Problem 3: "Mickey and Minnie's Dilema"
- Try St. Rita's Problem 12: "Environmental Blunders"
- Try St. Rita's Problem 26: "To be Normal"
- [Click here to try some Internet Mathematics]

Figure 6 - Example of a set of custom links designed for an individual lesson

In subsequent lessons at the Canadian school the network performance improved to acceptable levels. Even with the network running at reasonable speeds, the Canadian mathematics teacher -- who was the Head of Information Technology at the school -- noted that if she was doing the activity again she would still "try to have a second person in the computer room on the days that the computers are being used."

Issue 5: Offensive or Inappropriate Language

In general, it was rare that students used offensive language in publishing problems and critiques. However, there were two instances that were noteworthy. The first incident occurred in our very first trial of the Electronic Critique. A few students used inappropriate language when critiquing the example problems. It was the opinion of teacher and researcher present that this could have been avoided had we given students clearer expectations about just what was and wasn't acceptable, and if we had told them that the critiques were being monitored by other people outside of the school. Nonetheless, in our non-electronic studies, we had never had any prior incident of inappropriate language. Consequently, we concluded that it was preferable for a teacher to see critiques from their class before they were "released" to the original author.

The second incident occurred when a risqué problem was sent via a pseudonym to a Forum during a problem-posing lesson. In this case, one of the webmasters had to go and remove the problem manually from the site. However, given the privacy and monitoring of the Forums these items could be removed and dealt with quickly as internal classroom matters.

There were no apparent cases in which an inappropriate comment in one class was read by a student from another class.

Issue 6: The level of technology-specific knowledge required for teachers to use the Intranet autonomously and to monitor the information flow into and out of their classroom

In this study, the Forums and individual classroom links pages for all locations were maintained by the project researchers in Oxford and Toronto, who acted as "webmasters". In practice, there appeared to be advantages and disadvantages inherent in this approach.

The other members of the project team appreciated not having the responsibility for preparing and maintaining pages for the lessons they were teaching or observing; and, through Special Discussion Forums everyone could readily post information and requests to others on the project team. Generally, all requests were handled in a timely fashion and changes were made as needed, right up to the last moment before a lesson began.

Although the webmasters could react quickly, there were still incidents in which it was apparent that other members of the project team would have preferred to have been able to perform basic tasks like deleting messages, building Forums and preparing links pages themselves. An example was a situation in Australia when a request was made to delete a message from a Problem Forum and also insert a portion of a message that was inadvertently left out. On this occasion, it probably took more time to e-mail and explain the request to the webmaster than was required to make the actual corrections.

The Canadian teacher wrote that in doing the activity again she would want to "get involved and learn about the actual setup. If I wanted to do this again, I couldn't do it without some (quite a lot of) help".

5. Discussion and Conclusions

As more and more schools are becoming connected to the Internet, we need to ask ourselves how we can make appropriate (Levins et al., 1989) use of the World Wide Web in classroom environments. Two obvious uses of the Web are to display materials and process data. However, in considering the Web's applicability in mathematics classrooms, we need to ask:

- What mathematical items are worth displaying using the Web? Who should see them? and, Who should make these choices?
- What kinds of data should Web pages process for mathematics teachers and students? Who should see the results? Where should the data come from? How should it be processed? and, Who should make these choices?

In this study, we have explored one set of answers to these questions, influenced by our own philosophy, which draws heavily on the idea of using the technology to form cross-cultural "communities of inquiry" (Cudmore et al., 1996; English & Cudmore, 1998; Lipman, 1991). In our case, the mathematical items came *from the students* in the form of: possible survey questions; original statistics problems; and supportive yet critical comments about the mathematics problems themselves. The audience for students work was local and international peers, as well as a few selected adults. Similarly, the data to be processed came *from the students*. However, the students were given only raw results, and therefore they had to play an important role in deciding how it would be processed and how such analysis could lead to decisions and discoveries. Finally, the teachers -- being responsible for their students -- had ultimate control in monitoring what was displayed, and in moderating what was shared between their class and the outside world.

Our central conclusion is that semi-private Web-based Intranets (or Extranets) present an excellent medium for publishing, sharing and discussing mathematics problems created by students. In this exploratory study, we achieved flexible and efficient communication between teachers, students and university-based educators. Consequently, we are optimistic about the potential of Intranets to provide "laboratories" where problems are made, and "living galleries" where interesting student-made problems are collected, organised, attempted, appreciated and discussed.

Our emphasis on using the Web to foster *problem posing processes* is arguably outside the mainstream of what most people are currently doing with the World Wide Web in mathematics classrooms. However, the observed value of "publishing to audiences" -- and the contribution of such activities to student learning -- seems entirely consistent with the findings of Winograd (1991) and the better known literature on student publishing in subjects such as Languages or Art (Graves, 1983; Bereiter & Scardamalia, 1987).

At the same time, it is evident that we have not yet optimized our electronic implementation of the Problem Posing and Critiquing Activity. We are confident that it is valuable to consider the student as assuming two roles: one in which they create problems, and one in which they try other people's problems and give feedback. However, we still did not get the degree of recursion in the problem-posing process (illustrated by the iterative loops in Figure 1) that we would like to have seen.

The Intranet design has developed over the course of this study, and it needs to evolve further in future. Key design-related recommendations include:

- The Intranet needs to give teachers more freedom to initiate, monitor, and guide the flow of information between their classrooms and the Intranet. In future, additional automated tools should be incorporated which allow teachers to use their Web browser to set up: custom links pages, their own forums, survey forms, security preferences for their class, and more readily moderate what gets shared between their class and the outside world.

- Teachers should encourage students to be reflective and recursive in their problem posing activities. Word processing capabilities and the ability to submit work to the Intranet outside of class time should be taken advantage of to encourage students to take an iterative approach to their problem writing.

- Teachers should structure their Web-based lessons through a main links page that is customized for *that* particular lesson. By reducing navigation-related questions, this step alone was found to greatly increase the amount of work that students were able to accomplish in a particular lesson.

- Teachers should be encouraged to use the in-class brainstorming Forums, if they want students to suggest survey items for a data investigation.

- The Intranet communications should continue to be monitored, and students should know that this is being done. Before our next phase, we will also need to ensure that a code of conduct is put in place and clearly understood by students before they use the Intranet.

- It remains appropriate to design the Intranet for older browsers (Netscape 2.0 or above), but in the next phase the Intranet should employ integrated, on-line databases (rather than manually created result tables) to display survey results.

At the conclusion of the exploratory studies, we remain convinced that it is valuable to continue to employ and develop Intranets to foster mathematical inquiry. The importance of educational networks to encourage student inquiry is aptly described by Scardamalia (1997), who argues:

> A hallmark of student engagement in educational networks is the production of knowledge of value to others, not simply demonstrations of personal achievement. For school students this means producing ideas that others find valuable, including others with more experience... Systems that create a public presence for ideas and for group work have the potential of creating contexts of responsibility and pride, contexts in which individual and communal achievements reinforce one another and serve to ensure and even to accelerate continual improvement... The notion that students' ideas and resulting advances in those ideas should be centerfront in school processes -- not science, mathematics, writing, or reading tasks, and not games, projects, field trips, or other activities -- seems counterintuitive. How can one learn about content if students' ideas rather than that content are the focus of inquiry? What is at issue is NOT less

attention to core content or to activities that drive understanding. In contrast, we believe that the lesson to be learned is that a whole new layer of activity OVER-AND-ABOVE such content and related activities is required.

In this paper, we have begun to explore Intranets as one means of fostering and structuring these "new layers of activity" within the small window of time available in a crowded mathematics curriculum.

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Appendix A -- The Problem Critique Form

Problem Critique

(complete after answering problem on other side of this sheet)

date: ____________

Your Name: ____________

Title of problem you are critiquing: ____________

Author(s) of problem you are critiquing: ____________

1. Overall, do you think the problem is... (check one)
   ( ) excellent ( ) very good ( ) good ( ) fair

2a. What do you LIKE MOST about the problem?

____

____

2b. What do you LIKE LEAST about the problem?

____

____

3a. Can the problem be SOLVED? (check one) ( ) yes ( ) no ( ) not sure

3b. **If 'no' or 'not sure', why?**

____

4a. Is the MATHEMATICS in the problem EASY or DIFFICULT? (check one)
   ( ) much too easy ( ) too easy ( ) about right ( ) too difficult ( ) much too difficult

4b. **What was difficult?** ____________

____

5a. Is the WORDING of the problem CLEAR or CONFUSING? (check one)
   ( ) perfectly clear ( ) fairly clear ( ) a bit confusing ( ) very confusing

5b. **What was confusing?** ____________

____

6a. Is the problem INTERESTING? (check one)
   ( ) very interesting ( ) interesting ( ) a bit interesting ( ) might interest others but not me

6b. **What was interesting?** ____________

____

7. SUGGESTIONS FOR IMPROVING/EXTENDING THE PROBLEM: The author of the problem will be asked to improve and extend their problem. In your opinion, what could the author do to improve their problem (changes in wording, additional questions, etc.)

   1.

   2.

   3.

title of problem = whowhere
author of critique=J.L. (female)

Problem Statement:
Four friends met at the park one weekend. Their names were Sue, Tim, Jane, and Ben. One lived in a house, another in a caravan, another in a flat, and the other in a house boat. Janelived in the house. Tim did not live in the flat or the caravan. Ben did not live in the caravan. Where did Tim, Ben, and Sue live?

Details of solution to problem
First you establish that Jane definately lives in the house.Eliminates one option. Tim did not live in flat or caravan which leaves the houseboat. Eliminate that option . Two options left. Ben did not live in the caravan which leaves the flat . By the way Sue lives in the caravan .

Critique

1. Overall Rating=vg
2a. Like Most=It made you use your brain to eliminate the options .
2b. Like Least=Please use orginal names!
3a. Can it be solved?=yes
3b.
4a. Mathematics easy or difficult=too easy
4b.=
5a.= Is the wording of the problem clear or confusing?=a bit confusing
5b.= Why? =Why did they mention that they met in the park?It was irrelavant.
6a.= Is the problem interesting? =a bit interesting
6b.= What was interesting? Nothing was interesting , it's maths !!!! Really though it was quite interesting to try and solve .
7a. Suggestion #1=Don't give away the answer by saying'Jane lives in the house'. Make people really have to use their brain.
7b.= Suggestion #2=Use more people and more locations , in different parts of the world .Don't make the question too long though .

Appendix A: Example of the Results of an on-line critique

Appendix B

The following narrative describes the emergence of the OurQuestions.com Intranet design.

Beginnings

The genesis of our interest in Intranets occurred at the end of a earlier research study which investigated mathematical problem posing and critiquing, but did not include any computer-mediated communication. In 1996, one of the schools participating in our research study became connected to the Internet. The teacher involved suggested that it would be beneficial to the school and the students if some of the well constructed student-generated mathematics problems could be displayed on the school's new Internet home page. The teacher and his department were also keen to identify other opportunities for incorporating Internet technology into classroom instruction.

Publishing student problems on the Internet seemed to be a reasonably straightforward proposition. However, there were issues that needed to be considered and they fell broadly into two categories. First, were ones that Keiner (1997) has described as "typesetting" related, which would include issues such as: who would take the written problems and convert them to Hypertext Markup Language (HTML); what aesthetic choices needed to be made in the design of the HTML pages; and, who would arrange to put these documents on the school server. The second set of issues related to the public implications of a school's home page. These pages present a brochure-like image of a school to the outside world. Therefore, a school's administration has a responsibility for vetting all publicly accessible content. A school also has a responsibility to protect its students. Therefore, issues of consent and of privacy would need to be considered when publishing problems and any information about the authors.

Importantly, while it was possible to publish student problems on the Internet, the typesetting and vetting issues kept this from being *easy*, in practice. Consequently, in spite of our good intentions, we did not place any examples of student posed problems up on to the school's home page that year.

In July 1996, however, our enthusiasm was revived when we became aware that it was possible to password protect pages on most World Wide Web servers. Password protection appeared promising as a means to reduce our concerns about vetting and privacy. It was now conceivable that an entire class could put up their mathematics problems in a private area of the school's Web site, and an index page could be written that would make it easy, through hypertext links, for students to efficiently browse the problems posted by their classmates. At the same time, the pages could also be accessed from any computer in the world that was connected to the World Wide Web, provided the viewer knew the address and the password for the page. Thus, it would be possible for a class of students in another country to view the students' problems if their computer network was connected to the World Wide Web, and if they were given authorization to access these pages.

However, putting passwords on areas of the school's Web site was not a straightforward proposition. This was because the Oxford school at this time did not have its own on-site

Web server, but instead the school's pages were located on a remote server at a large computer company. At that time, only one person in the school was authorized to upload documents to this server. Consequently, it was possible but not easy to use the school's Web site to privately share student problems.

We decided to pursue other means of creating password protected Web pages, and were especially influenced by Bernard's groundbreaking book, *The Corporate Intranet* (1996). Bernard espouses Internet access for members of an organization. However, he notes that it is probably most valuable in enabling members with a route (through Internet access, the page location, and password) to remotely and cheaply access an Intranet. The Intranet is an area where groups and sub-groups in an organization -- with appropriate security -- can quickly access, contribute, and distribute Web-based information collectively or privately, as needed. The only hardware required is a direct connection to either the Internet or the Intranet, and the only software required is a familiar Web browser, such as Netscape or Internet Explorer. Thus, if members know how to "surf the Internet" they will be able to fully use the Intranet.

Bernard (ibid.)suggests that to be most valuable, the designer needs to take the Intranet and "set it free" amongst the members of an organization . Implicit in this, is the idea that the key users must have input and control over what the Intranet does now and is able to do in the future. For us to have that level of control, we decided that we needed to set up our own Web server, independent of any one school or institution.

Creating a Project Intranet

In a basic sense, we now understood that our Intranet would have two main capabilities: the ability to serve web pages to authorized individuals anywhere in the world (provided they have an Internet connection and any required passwords); and second, the ability to automatically accept, process and distribute data using Web-based interactive forms.

Interactive forms were viewed as the best way forward to ensure that "typesetting" could occur automatically; in effect, a user would be able to fill out a form and the Intranet's form processor could automatically display this information on a new page of HTML, create a hypertext link to this in a document index, and send an e-mail if needed to a distribution list to notify others that new information had been posted. All of this could be done, without the user needing to know any computer programming languages (such as HTML).

Our initial Web server was placed on a small Macintosh computer connected to the Oxford University ethernet. This gave us an opportunity to explore Intranet server architecture and gain experience creating and password protecting simple HTML documents. However, we were concerned that this server might not be able to adequately handle the traffic of 30 students attempting to access it from a classroom far away in Australia.

We received a grant to enable us to move our Intranet site to a commercial host (Webcom.com) in the United States. This host was selected because it was relatively inexpensive, its servers could support increasingly high levels of traffic, and we would not need to worry about maintaining the server hardware and software ourselves. The service was especially attractive because it included access to a sophisticated forms processor which well documented and highly customizable. A member of our research team assumed responsibility for developing configuration files which would enable us to design forms that could not only be used to post student generated problems, but also be used to process discussion forums, on-line problem critiques and statistical surveys. We obtained a custom domain name (ourquestions.com) to make our site easy for project members and students to remember; this also effectively hid the true identity of the Web hosting service -- which meant that we could move the site to another host in future without having to change the public address of the Web site.

In developing the site at the commercial host it was essential to understand the cost structure for the various services that we required. The key cost contributor was the amount of hard disk storage space used at the site, followed by surcharges that would be applied if the network volume (ie. the cumulative size of files requested by users and visitors to our site) exceeded particular monthly limits. Thus, from a design standpoint we needed to aim to keep the file sizes for forums, critique sheets, etc. to a minimum. This had the added benefit to users of ensuring the Web pages at the site could be loaded quickly by the Web browser.

Another consideration was the minimum version of browser software that would be required to access our site. If we designed to the higher-end browsers (which in 1996 was Netscape 3.0 and today is Netscape 4.0 or Internet Explorer 4.0), we would be able to incorporate fancier styling and graphical features, and incorporate mini-programs written in the Java programming language. However, after consideration of our aims as well as our cost structure, we decided to design our site so that it would work well with lower versions of Netscape (version 2 or above). The advantage of doing this was that this meant that the school-based equipment required to access the site was more modest. This was important, since we did not want to develop a problem posing and critiquing workspace that could only be accessed by schools from countries with the very latest and most expensive equipment.

Finally, the other major consideration at this stage was that we decided not to include real-time "chat" or video-conferencing facilities into our Intranet design. This was because we decided that the initial studies were to involve students from England and Australia, and due to the time difference (10 hours) the students from the two classes would never actually be in school at the same time. Thus, we decided to focus our efforts on developing a system for asynchronous communication.

The following section briefly chronicles the key features of what became the cornerstone of our Intranet communication: the Forum Messaging System.

Development of the Forum Messaging System and the Intranet Gateway

As Downing & Rath (1997) noted, an Intranet can be a successful innovation when it can perform a task that becomes essential to its user group. In our case, it became essential in at least two areas. It became an essential "project workspace" for the researchers and teachers, where we could efficiently plan, report, conjecture, and present observational data. Furthermore, the Intranet was absolutely central to any on-line publishing, sharing and critiquing of problems by students. The critical role of the Intranet in our efforts to meet these two principal needs is apparent in the discussion of the field studies later in this paper.

The building block for these communications was the Forum Messaging System. This system was used to create custom semi-private Forums in special areas of the Intranet Web site. The basic structure of a Forum involves three principal parts. An *index* page is used to display a tabular index of the messages that have sent to the Forum. Each *full message* is contained on its own separate Web page. The third component is the page which contains an on-line form for *new message entry.*

A user will access a Forum by entering its location into their web browser. Once inside the Forum, the user can read the existing messages or send a new message. The message entry page is a Web-based form which typically contains boxes where the user can input their name, the subject of their message, and the main body of the message. When a new message is submitted the following key steps occur *automatically*. A new Web page is created at the Intranet to display the full message, and this page includes an index number and the date and time when the message was received by the California-based server. A new index page is created to replace the previous index; this page is identical to the previous index except that a row is added that displays the author's name, subject, and date and time of the message. The index page contains hyperlinks to each full text message as well as the message entry page. At the same time as these pages are created, e-mails are sent to notify selected individuals that a new message has been posted to that particular Forum.

An important technical breakthrough in our project was achieved when one of the researchers (J. Aczel) developed a simple but elegant system which automated the Forum creation process. This enabled new Forums, password protected if necessary, to be created at an appropriate location at the Intranet remotely and in a manner of seconds. Importantly, the amount of hard disk memory required by each new Forum was minuscule: the components of a new Forum used less than 10 Kilobytes (K) in total, and each new message was typically less than 3K in size. This is small when one considers that a single picture in a Web page often occupies more than 20K by itself. It was not necessary to know HTML to use the Forum messaging system. However, a user could choose to include HTML commands in their pages; therefore, a message could contain hypertext links to direct people to new Forums, diagrams, pictures or other materials located elsewhere on the local Intranet or in the wider Internet.

Electronic Problem Posing and Critiquing Forums were direct descendants of the basic Forum Messaging System. Their structure and navigation was slightly more complex, in that they included a Forum for the posed problems, links from the problems to a central electronic critique sheet, as well as a Forum where filled out critiques were displayed.

Later in the project we would add various customization features to Forum Messaging systems to improve the navigation, message previewing, e-mail notification, and message display options. This process of optimizing the Forum user-interfaces -- and the creation systems for both "Basic" Forums and "Problem Posing and Critiquing Forums" -- is one ongoing aspect of our research.

Another important aspect of the Intranet design concerned the manner in which the users would access the particular Forums that they needed. As noted above, they could access the Forum if they simply typed in the address (URL) for the Forum's index page in their browser. If the Forum was password protected, they would be prompted for a username and password before they could actually view the pages there. However, to enable users to find pages more efficiently we decided to place a publicly accessible gateway at the Intranet's home page (http://ourquestions.com). On this page, there was various public information about the project. It also contained a password protected link to an internal directory of the various active project Forums. This directory was intended for the use of the teachers and researchers participating in the project. We took a different approach to the Forums that were to be accessed by students. When the students needed to be able to get to a particular directory, we normally would update the gateway page with a temporary link that would say something like "Links for Mr. Wright's Class" that would take them directly to the Forum required.

At this point, the Intranet was ready for the initial trials.

Appendix C

Intranets and the Research Process

A recurring theme in the Forum conversations between the teachers and researchers, beyond the scope of the items addressed in section 4 of the main report, was the positive impact that Intranet use appeared to have on the openness and effectiveness of the research process. The following discusses this informally:

As researchers, we learned that our project team was more efficient -- and our data collection and immediate analysis more rigorous -- when we used specific project Forums religiously. We stumbled across this accidentally. Unexpected changes in one of the authors geographical location, meant that the early studies in Oxford required a project leader in Toronto, a researcher in Oxford, and a teacher in Oxford to collectively and intimately be involved in the micro-planning of the initial studies. To our surprise, as the records at the relevant Forum (http://ourquestions.com/Forum/Thread3) display, we were not only successful but using features like hypertext, e-mail and phone calls strategically, we actually used up surprisingly little time in our otherwise busy schedules along the way. For example, we estimate that the amount of teacher time spent on all the Oxford-based research (ie. which required his attention outside of regular teaching activities), as shown in Table 1 of the main report, was an astonishing total of less than 5 hours. The comments he made were frequently brief, but they were always timely and often crucially important.

We feel confident in our claim about the value of using Intranets to organize multi-site research projects, since later in the project we did not use the Forums to the same degree as at the outset, and our communications suffered to some extent. In both Brisbane and Toronto, the local research teams were self-contained and therefore we did not need to have the broader conversations to be sure that we knew what happened in the last lesson and to be clear on what was needed for the next lesson. Our experience in writing this report has shown us that without the Forum dialogue recorded it was more difficult to collectively research what had transpired (especially at locations where we weren't personally present). Along the way, we no doubt missed opportunities when a brief teaching idea, or methodological tip, from others in other locations would have improved the local research.

As such, we learned what others have been learning about Intranets and Extranets in the business world. First, a great deal can be achieved using small amounts of time from critical people at the critical time. Second, it helps to be able to distribute the workload, and if all the "works in progress" are in a central location then people can take the initiative to see things that need to be done and "just do it". Third, people are often quite happy to enter data -- and look at communications -- if it serves their purposes. In the business world this means better customer service and satisfaction (consider on-line banking, for example), but it also means that the people providing the service -- or conducting the research -- don't have to re-enter data that could otherwise have been entered by user. For example, the problems in Figure 2 (in the main report) did not need to be re-typed for this report; we had hypertext links to the research data and could simply cut and paste them from the original Forums.

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